

## I. INTERNAL CORONA PROTECTION

This covers shielding between adjacent racks in the stack and between parts on individual racks. The voltages encountered are generally 92 KV between racks and 46 KV within each rack.

### A. Shielding Between Racks

1. Corona ring diameter and spacing. Design is such that the calculated gradient is under 20% of the corona starting gradient from Peake's formula. These rings are designed primarily for external shielding.

2. Spacing and shielding between racks. Neither 61PTL41, RCA Tradex bank 32F18, BPA 345 KV series and shunt banks, nor the several "pancake" DC banks have configurations and voltage combinations that serve as close precedents for this design. However, rack design minimizes protruding points or edges, and theoretical calculations show 1" diameter spheres or 1/8" diameter tubes should be corona free at these spacings and voltages. Therefore, slight rounding off of any trouble spots appears feasible for solving any corona problems. Rack drawings are calling for 1/16" radius on all external cut edges and 1/8" radius on all corners. Corona rings are large but have to be too close to the rack for optimum internal corona protection.

3. Inter-rack insulators (Locke 29153). These have 250 KV impulse withstand, 100 KV, 60 cycle wet withstand ratings and will be used at 92 KV DC. Lower rated Locke 7785 have very low RIV at this voltage and R. Weller, Insulator Dept. Engineering, sees no reason why the 29153 shouldn't be as good on RIV (per 12/19/62 phone discussion and letter of that date to J. E. Berryman).

### B. Shielding Within Racks

1. Nichrome wire buswork. Calculations show gradient would be 18% above corona starting gradient for #10 wire if unprotected, so a high resistance shield (Herkolite tube with conductive paint) is provided in parallel with the wire. It also shields the capacitor bushing end. The hemisphere terminations on the shields have a calculated gradient well below 1/2 the corona start gradient. The large shield size is a result of mechanical considerations.

2. Rack to corona rings. Calculated gradient is far below 1/2 the corona start gradient. Table II of 60PTL36 (1" x 14" toroid at 1') substantiates the calculation.

3. Series resistors to corona rings. If spheres of the same diameter replaced the tubular shapes at the cross over point, calculated gradient would be well below the corona start gradient.

4. General. Design minimizes exposed points and edges. Drawings call for 1/16" radius on all external cut edges and 1/8" on corners. Calculations (see A2) show minor additional smoothing should clear up any trouble spots.

## MEMORANDUM

Title: Design of Corona Protection for Allis Chalmers/BPA 550/825 KV DC Capacitor Banks Cat. 32F28G1

Ref: Drawing 537D932. Two such .35 uf stacks are being supplied.

Requirements: (In AC/BPA Spec.) Are "Each filter capacitor bank shall be essentially corona free at 900 KV DC line to ground. The radio noise as a measurement of corona shall not exceed 250 microvolts at plus & minus 550 KV at no load and 100% rated load as measured at the output terminals by a modified NEMA circuit." In the 550 KV mode both stack bottoms are grounded and the tops are respectively at plus & minus 550 KV. In the 825 KV mode both stack bottoms are tied together and are at 275 KV, the top of one is at 825 KV, the top of the other (including the top 3 racks which are shorted out) is grounded.

### Design Considerations:

1. Atmosphere to be clean (in BPA's pressurized bubble with filtered air intake per discussions with L. Nickels of AC; assume erratic and low corona starts per Table I of 60PTL36, therefore do not apply).

2. DC radio noise levels for either polarity tend to be less than for same 60 cycle crest. (Re: Adamson & Hingorani, "HV DC Power Transmission" page 211; this gives a useful basis for comparison with AC data.)

3. Calculation of theoretical starting gradients (Peake's formulae) and comparison with calculated gradients at surfaces of conductors for tube to tube, tube to plane, sphere to sphere, and sphere to plane configurations similar to those encountered in the equipment.

4. Reports 60PTL36 and 61PTL41 on HV lab tests sponsored by Hudson Falls to investigate DC corona on toroids, insulators, representative structures, etc.

5. Comparison with the "1,400,000 volt Constant Potential X-Ray Equipment" built for National Bureau of Standards and reported in GE Review, volume 43, no. 7. Also see photo 786028. Total corona and surface leakage loss current at full voltage at either polarity was only 0.16 ma indicating very conservative design.

6. ASEA's recommendation that a 2.5 meter diameter ring of .3 meter section diameter would be adequate for 900 KV. Recorded in Glenn Breuer's 7/23/62 letter to D. M. Demarest in Holyoke.

7. The complexity of the bank results in many possible corona generating areas. To avoid having several small radio noise sources add up to an unacceptable total RIV level, the design endeavored to keep as many areas as feasible safely below the corona starting level.



- b. The 18" corner centerline radius is more conservative than the 12.5" radius of the X-ray toroids.
- c. Tubular section sizes have been chosen to be roughly proportional to voltages using the 6" X-ray shield at 1,260 KV as a reference. Five of the 11 shields are somewhat smaller than the proportion would dictate, however, the design is conservative as is the act of proportioning diameters to voltages for sizes smaller than the reference. When the latter effect is taken into account, only the top ring is smaller than proportions dictate.

2. Calculated surface gradients from some of the tube diameters used on these rings equal or exceed the calculated corona start gradients for the tubes. This is also true for the 1,400,000 volt tube. There is a beneficial "bundle" and grading effect in both multi-ring configurations. By visual inspection this appears at least as good in the AC/BPA bank as in the X-ray equipment.

3. 61PT141 page 5 and 7 shows shielding of a similar configuration was effective to an 8" depth between corona rings spaced 43" apart. Shield spacing vs. depth of shield parts for the AC/BPA bank sides is more favorable than this.

4. Calculations of corona start conditions were based on spacings of 9' to a plane of opposite polarity. This is a more severe condition than is found in Allis-Chalmers' layout drawing 12-500-921 and discussions with L. E. Nickels of AC. However, at this spacing gradients are almost at the levels for infinite spacing so this does not lead to overconservative design.

5. At the 550 KV connection side shields should be noise free because their design is closely proportioned to the referenced conservative X-ray equipment for the 825 KV connection.

C. Bottom Shielding - the lowest side shield, a ring of 2.375" O.D. pipe, also serves as the bottom shield. In the 825 KV connection its voltage is 275 KV.

1. Calculated surface gradient for 2.375" O.D. tube at 300 KV from a plane 40" away is 67.4% of corona start gradient so the ring itself should be clean.

2. 60PT136, page 7, tests on 2-1/2" x 30" toroid suggests adequate reserve for the ring itself.

3. BPA series capacitor 36F358G1 for 345 KV AC line has a comparable (282 KV) peak voltage to ground. Tests 59PT209 showed it free of visible corona. Structural configuration is comparable. Spacing to ground is over twice that of the subject DC equipment, but the shield on the latter is relatively lower for more effective shielding and also of larger cross section. For small point sources the spacing to ground difference would be negligible.

4. The same base insulators (3 Locke 7785) were tested (60PT136, page 7) and were visually corona free up to 370 KV, either polarity.

5. At the 550 KV connection the bottom shield is grounded and the bottom rack is at 45.8 KV. No problem here.

## II. EXTERNAL CORONA PROTECTION

This covers shielding for the rack to the environment at top, sides and bottom.

A. Top Shielding is to be a Rectangular "Ring" of 1' Diameter Tube with Corner Elbows Having 18" Centerline Radius. Maximum Voltage is 850 KV when Terminal Voltage is 900 KV. Bases for Design Included:

1. ASEA recommendation of a toroid of 2.5 meters diameter and 0.3 meters cross section.

2. The shield on the referenced 1,400,000 volt X-ray tube cathode if reduced in size proportionately to an 850/1400 voltage reduction would have a 44.3" horizontal diameter and 29.2" vertical depth. This proportion reduction is a conservative step and the cathode shield is conservatively designed to begin with.

3. Calculations show a 12" diameter tube even if only 9' from a plane at 850 KV would have a surface voltage gradient below 50% of corona start gradient.

4. Corner elbows are not equivalent to either tubes or spheres. However, a comparison can be made with a 2-1/2" x 30" aluminum toroid which had about 450 KV positive and negative corona start 6' from a plane (60PT136 page 7). If AC/BPA shield elbows were joined to make a toroid, it would be 12" x 48". Calculations for simple spheres and tubes at the same voltages and spacings considered for these toroids are as tabulated below. (See bottom of page 5 of this memo.)

The calculated corona situation of the 2-1/2" sphere is much less favorable than for the 12" sphere which indicates the 12" toroid or ring should be corona free. Tube comparisons are similar.

Outside corner radius of curvature for the 12" toroid or ring is not double that for the 2-1/2" ring although voltage considered is doubled. However, the 404%/186% sphere comparisons and favorable reserve shown in the 12" tube calculation (II, A, 3) indicates the corner will not be too sharp. The corner problem is the main reason for the large tube size.

5. At the 550 KV connection the top ring is at 504.2 KV. It should be noise free because design is governed by the 825 KV connection. An isolated 12.75 sphere at 504 KV from a plane 9' away has a calculated gradient only 104% of the start gradient.

B. Side Shielding - the 5 rings immediately below the 12" top rings are 3-1/2" O.D. pipe. The lowest 6 rings are of 2.375 O.D. pipe. All 12 have 18" centerline radii on their corners.

1. The 1,400,000 volt X-ray tube is shielded with 9 identical toroids having an outside diameter of 31" and a tubular section measuring 6". Maximum voltage (on the upper one) is 1,260 KV.

a. The AC/BPA banks have a rougher configuration than the smooth Herkolite cylinders on the 1,400,000 volt tube; consequently, vertical spacing is made closer to improve shielding effectiveness of the ring.



III. GENERAL

A. Air strikes and clearances are generally 6" minimum for 45.8 KV, a 31% margin over the commonly used 10 KV per inch.

B. The fact that the specified radio noise test at 550 KV will be on a 0.35 uf capacitor bank should have a profound influence on RIV measurements, especially with the coupling capacitor in the order of 0.002 uf. Any corona burst should draw its current largely from the capacitor bank instead of the coupling capacitor, thereby greatly reducing both the current through the metering resistance, and the RIV indication from what might occur if a low capacity device were tested. This effect may be mitigated somewhat because of the stiffer capacitor bank supporting heavier corona bursts.

C. The weakest points of the design regarding RIV are probably the (28) 7-1/4" cylindrical Steatite insulators with metal tapped inserts in each end used in each stack at 45.8 KV and the one top terminal insulator, Locke 29007, also used at 45.8 KV. However, the capacity of the bank is expected to help any such weak points as discussed above. Space problems made larger insulators undesirable.

D. Substantial help from the following in working out the corona protection features is acknowledged with thanks:

- J. J. LaForrest - Bldg. 9-205 - Pittsfield Works
- A. F. Rohlfis - 9-203 - Pittsfield
- G. D. Breuer - Schenectady
- R. Weller - Insulator Dept. - Baltimore

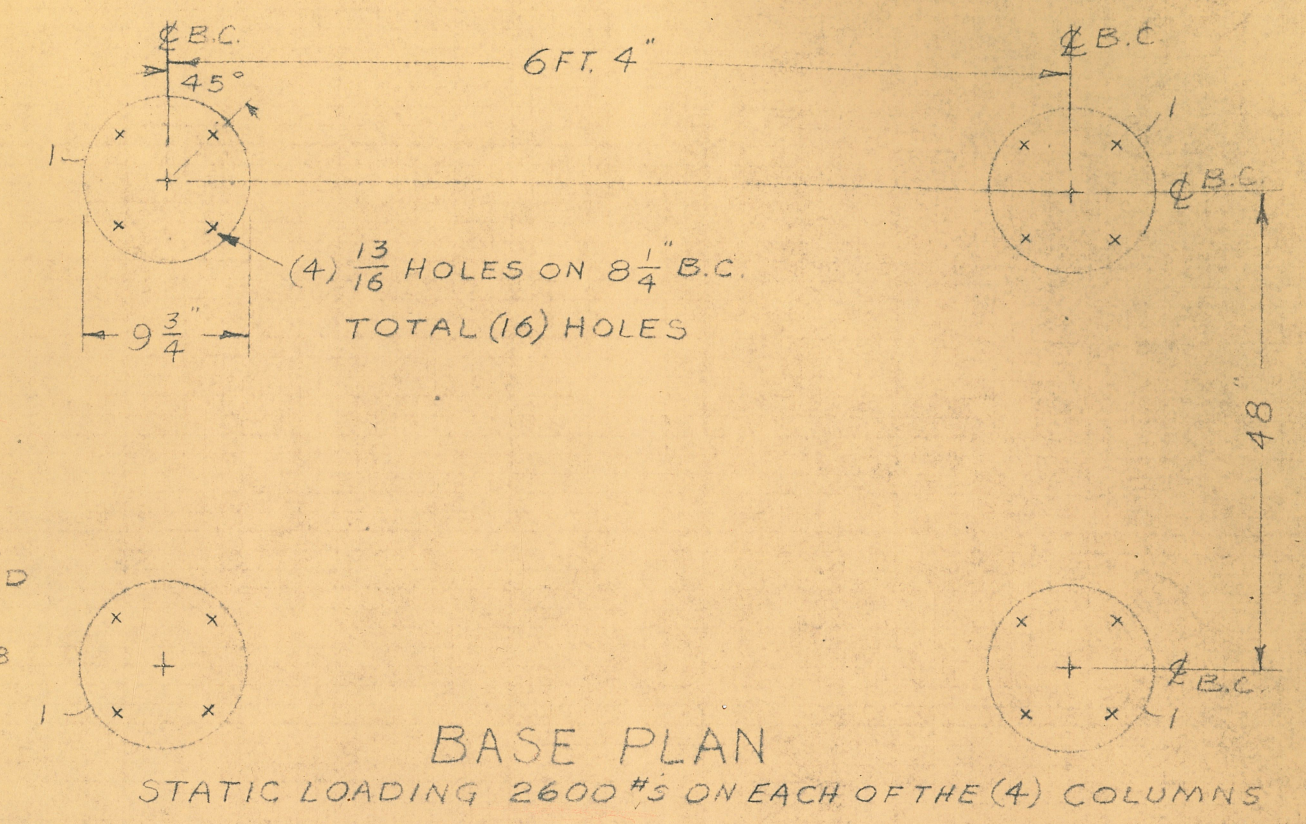
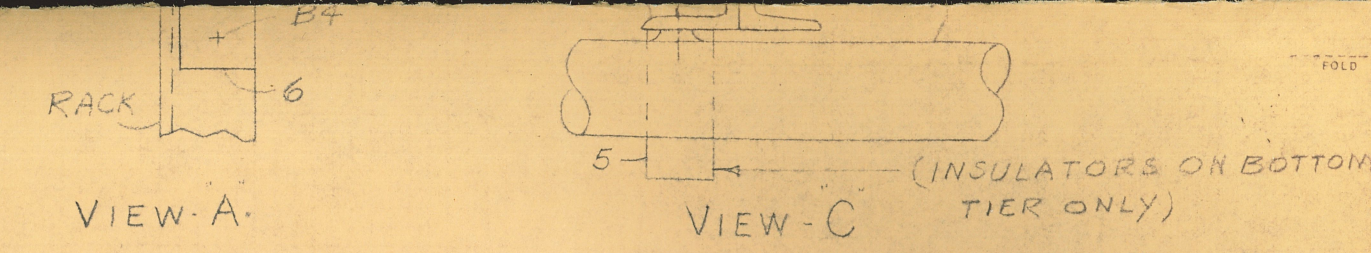
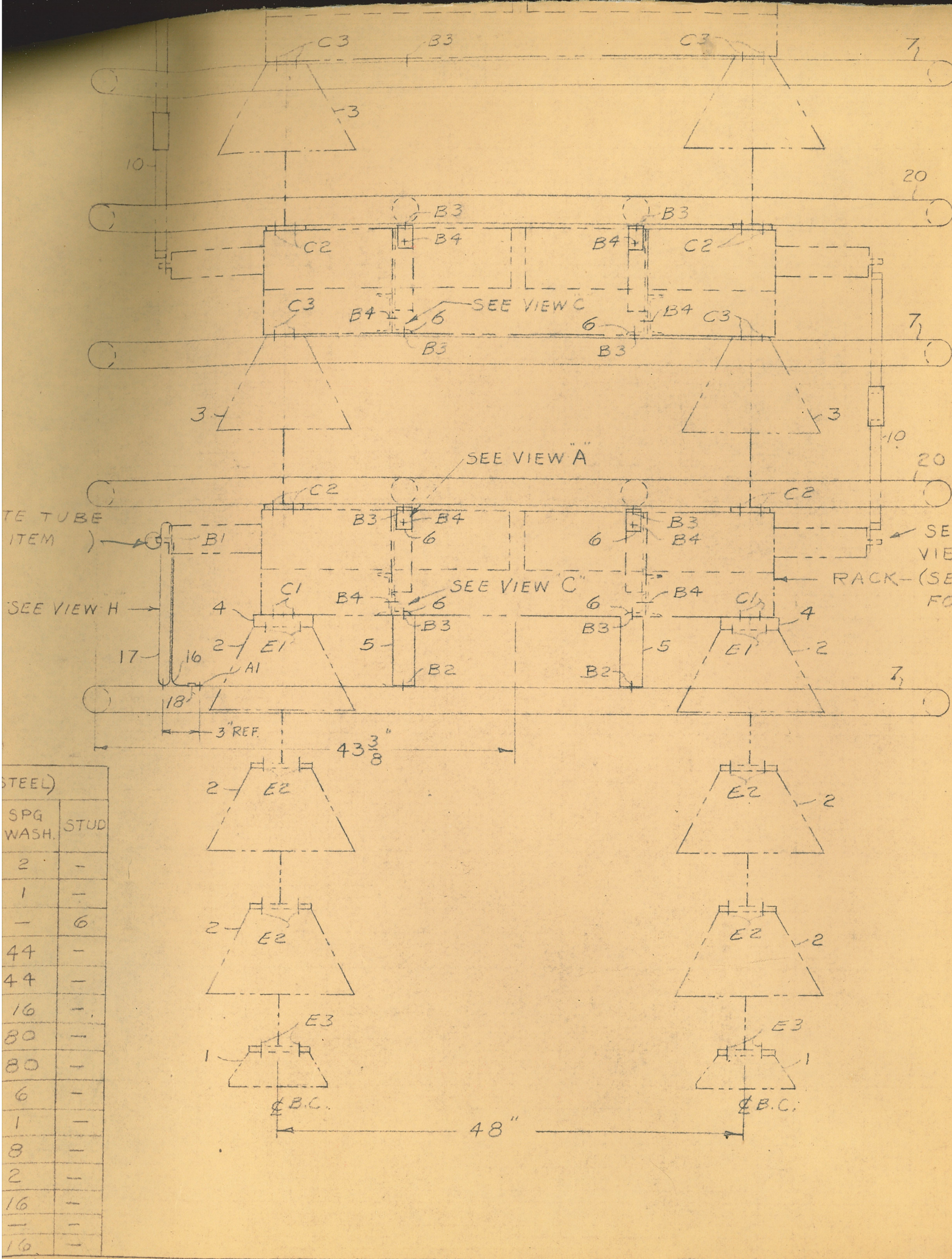
89 B  
G. E. Berryman  
Power Capacitor Equipment Engineering  
Ext. 488

\*dc  
January 14, 1963

| Shape  | Dia.   | Volts | Space to Plane | Calc. Grad. % of Start Grad. |
|--------|--------|-------|----------------|------------------------------|
| Sphere | 2-1/2" | 450   | 6              | 404%                         |
| "      | 12.75" | 900   | 9              | 186%                         |
| Tube   | 2-1/2" | 450   | 6              | 85.1%                        |
| "      | 12"    | 900   | 9              | 51%                          |

- cc: J. J. LaForrest  
A. F. Rohlfis  
G. D. Breuer  
J. Talentinow - Holyoke  
M. Marinucci  
D. H. Nichols  
A. G. Vail  
N. M. Neagle





- NOTE #1- FOR AIR CONTROL SYSTEM SEE 106C1462
- 2- FOR RACK ASM. SEE 537D933
- 3- TREAT ALUMINUM CONTACT SURFACES WITH PENETROX-A; WIRE BRUSH OR RUB WITH EMERY CLOTH. WIPE OFF EXCESS AFTER ASSEMBLY.

| DESCRIPTION OF GROUPS    |                         | REVISIONS                                                           |                           | PRINTS TO |       |
|--------------------------|-------------------------|---------------------------------------------------------------------|---------------------------|-----------|-------|
|                          |                         | <p>PLEASE EXCUSE APPEARANCE OF THIS PRELIMINARY COPY</p> <p>94B</p> |                           | 129       |       |
|                          |                         |                                                                     |                           |           |       |
|                          |                         |                                                                     |                           |           |       |
|                          |                         |                                                                     |                           |           |       |
|                          |                         |                                                                     |                           |           |       |
| MADE BY<br>C. J. Russell | ISSUED<br>C. J. Russell | APPROVALS                                                           | CAPACITOR<br>HUDSON FALLS | 537D932   | SH NO |



FOLD

D

E

F

H

18 FT 3 3/4"

30

11 FT 1 1/2"

40 5/16  
20 1/2  
15 1/2  
15 1/2  
15 1/2  
15 1/2  
13 8 5/16

12 1/2  
13 8 5/16  
12 1/2  
12 1/2  
12 1/2

RACK (SEE 537D933 FOR ASM.)

SEE VIEW J

SEE VIEW C

SEE VIEW A

SEE VIEW H

HERKOLITE TUBE

BOTTOM CORONA RING IS LV TERMINAL (EITHER POLARITY)

REG WASHER  
VIEW J

HERKOLITE (537D933)

| BOLT SCHEDULE (ALL HARDWARE TO BE GALV. ST) |             |                |      |     |            |
|---------------------------------------------|-------------|----------------|------|-----|------------|
| CODE                                        | DESCRIPTION |                | BOLT | NUT | REG. WASH. |
|                                             | TYPE        | SIZE           |      |     |            |
| A1                                          | HEX. HD.    | 1/4-20 x 3/4   | 2    | -   | -          |
| B1                                          | HEX. HD.    | 3/8-16 x 1 1/2 | 1    | -   | 1          |
| B2                                          | FULL THD.   | 3/8-16 x 1 1/4 | -    | -   | -          |
| B3                                          | HEX. HD.    | 3/8-16 x 1     | 44   | -   | 44         |
| B4                                          |             | 3/8-16 x 1 1/4 | 44   | 44  | 44         |
| C1                                          |             | 1/2-13 x 1 3/4 | 16   | -   | 16         |
| C2                                          |             | 1/2-13 x 2     | 80   | 80  | 80         |
| C3                                          |             | 1/2-13 x 1 1/2 | 80   | -   | 80         |
| C4                                          |             | 1/2-13 x 1     | 6    | -   | 6          |
| C5                                          |             | 1/2-13 x 1 1/2 | 1    | 1   | 1          |
| C6                                          |             | 1/2-13 x 2     | 8    | -   | 8          |
| C7                                          |             | 1/2-13 x 3 1/2 | 2    | -   | 2          |
| E1                                          |             | 5/8-11 x 1 1/4 | 16   | -   | -          |
| E2                                          |             | 5/8-11 x 1 1/4 | 32   | -   | -          |
| E3                                          | HEX. HD.    | 5/8-11 x 1 1/4 | 16   | -   | 16         |



UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:

APPLIED PRACTICES

SURFACES

TOLERANCES ON MACHINED DIMENSIONS

FRACTIONS

DECIMALS

ANGLES

REV. NO.

CONT ON SHEET

SH. NO.

TITLE ASM.

CORONA RINGS &amp; STACK

FIRST MADE FOR 32F28 GIBPA INV 9488 (GE REQ 398-81055)

2B HOLES

CUSTOMER'S CONNECTION TUBE

8 FT. 3"

HV TERM FOR 6" O.D.  $\frac{1}{16}$ " WALL AL. TUBE (FOR EITHER POLARITY) SEE VIEW E

SEE ENLARGED VIEW F

EM

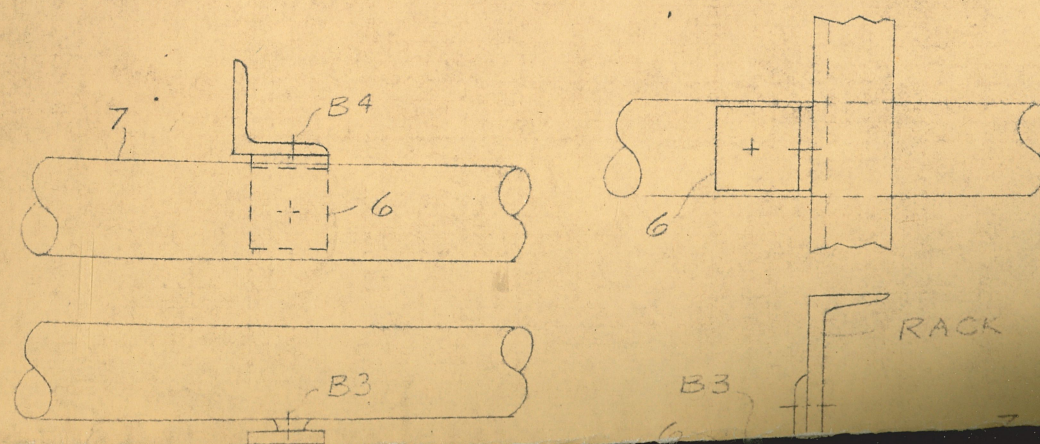
TO BE INST NG

AI

IN ITEM 7 AT ASM.

| QTY | ITEM NO. | NAME                    | DWG. NO. AND/OR DESCRIPTION               |
|-----|----------|-------------------------|-------------------------------------------|
| 21  | 4        | ADAPTER                 | LOCKE CAT. 7791                           |
| 22  | 12       | INSULATOR               | LOCKE CAT. 7785                           |
| 23  | 20       | INSULATOR               | LOCKE CAT. 29153                          |
|     | 4        | ADAPTER                 | LAPP CAT. 20155                           |
|     | 4        | INSULATOR               | 942A585 G3 $7\frac{1}{4}$ " LG.           |
|     | 44       | ANGLE <b>AL</b>         | 106C1454 P 36                             |
|     | 3        | 7 CORONA RING ASM.      | 537D936 P23 AL 2" IPS. SCH 40             |
|     | 3        | 8 CORONA RING ASM.      | 537D936 P22 AL 3" IPS. SCH 40             |
|     | 1        | 9 CORONA RING ASM.      | 537D936 P21 AL $\frac{1}{8}$ " W-12" O.D. |
|     | 10       | 10 SERIES RESISTOR ASM. | <b>780-2</b>                              |
|     | 1        | 11 INSULATOR            | LOCKE CAT. 29007                          |
|     | 1        | 12 PLATE <b>AL</b>      | 106C1454 P 32                             |
|     | 1        | 13 BUSTUBING <b>AL</b>  | 537D936 P26 AL 1" IPS. SCH 40             |
|     | 1        | 14 CHANNEL <b>AL</b>    | 106C1454 P 31                             |
|     | 4        | 15 ANGLE <b>AL</b>      | 106C1454 P 37                             |
|     | 1        | 16 NICHROME WIRE        | 100 FT. ROLL AWG #10                      |
|     | 1        | 17 CONNECTION SHIELD    | 537D936 P27 AL 1" IPS. SCH 40             |
|     | 2        | 18 STAKON TERM.         | 115A1609 P127 T & B CAT C-71              |
|     | 2        | — COMPOUND              | PENETROX "A" 50Z. TUBE                    |
|     | 2        | 19 CORONARING ASM.      | 537D936 P24 AL 3" IPS. SCH 40             |
|     | 3        | 20 CORONARING ASM.      | 537D936 P25 AL 2" IPS. SCH 40             |

CODE XLIST





2

3

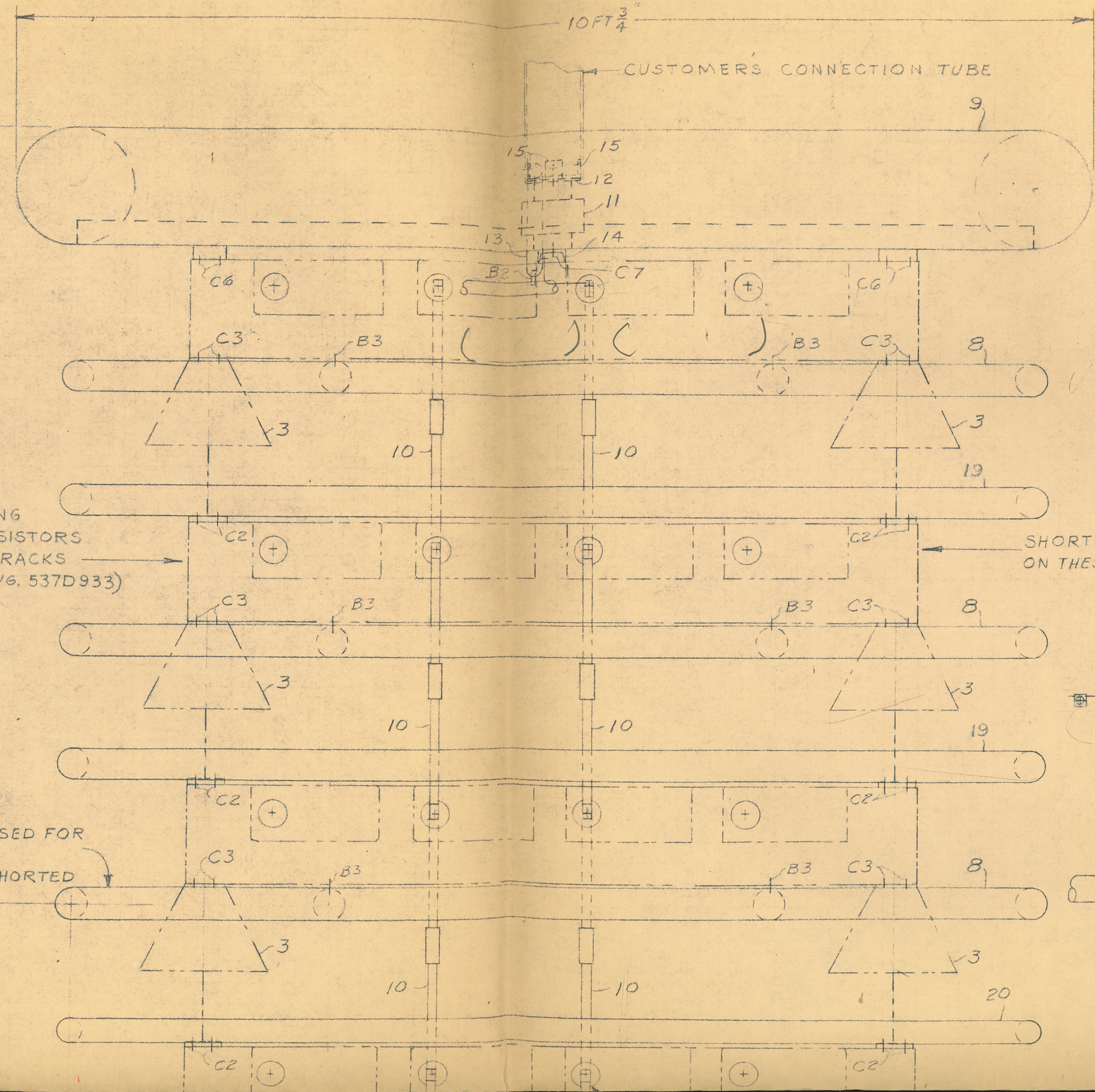
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5

A

B

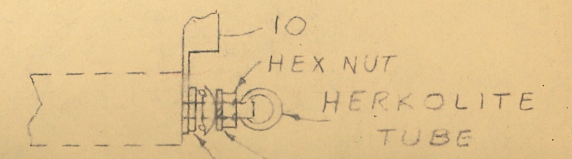
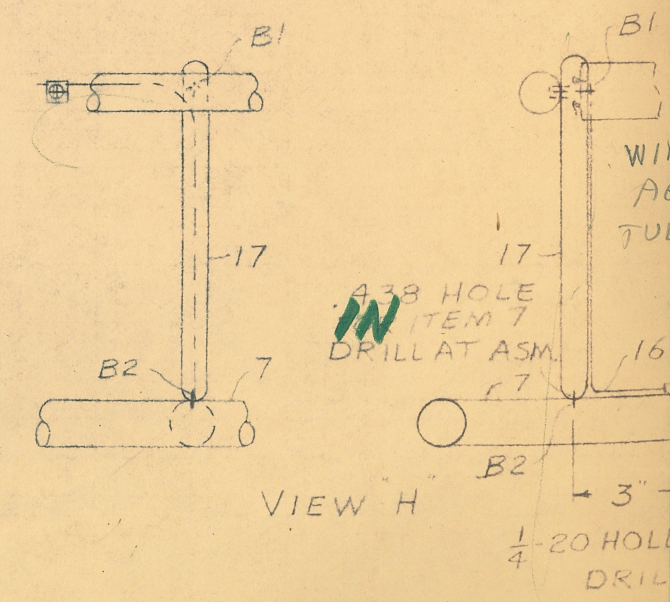
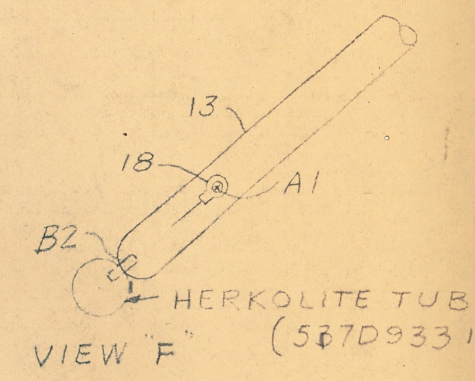
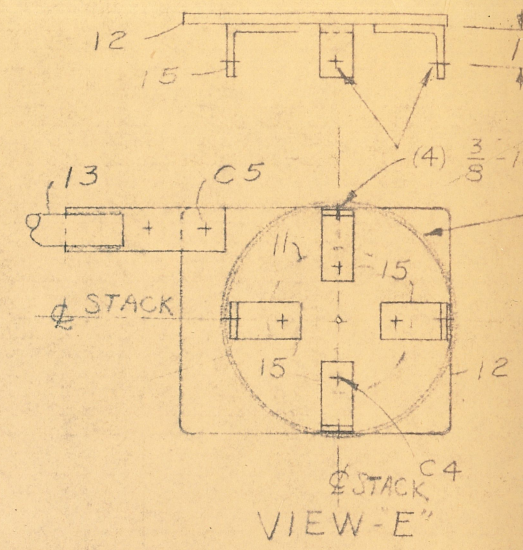
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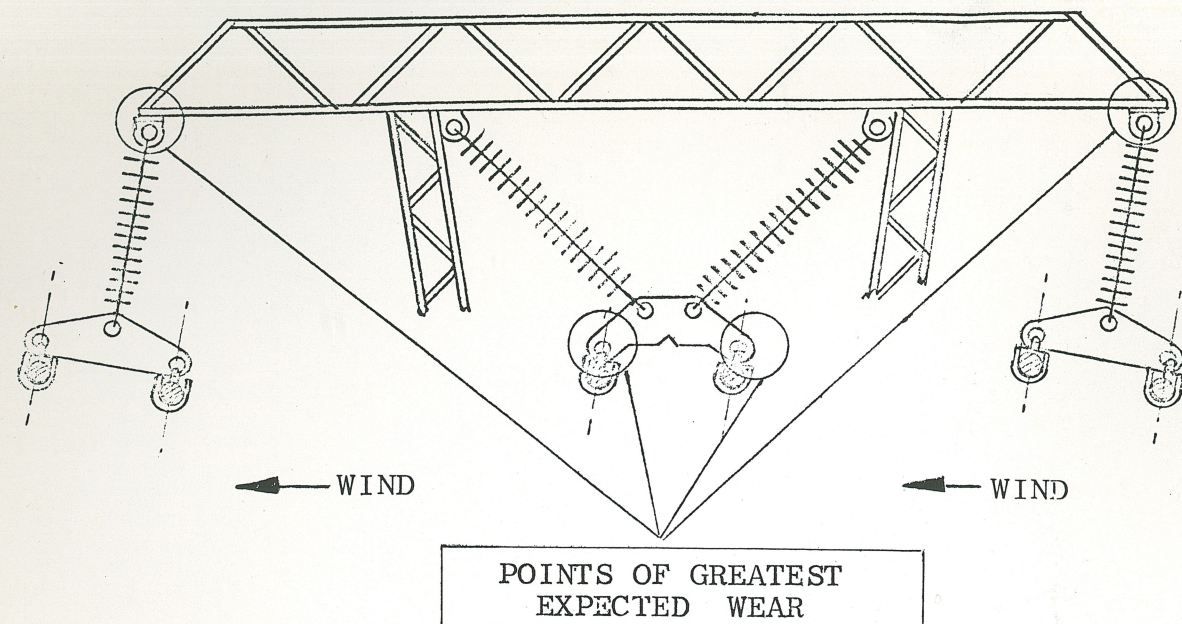
VOLTAGE GRADING  
AND DISCHARGE RESISTORS  
ON THESE ENDS OF RACKS  
(SEE RACK ASM. DWG. 537D933)

SHORTING SWITCHES  
ON THESE ENDS OF RACKS

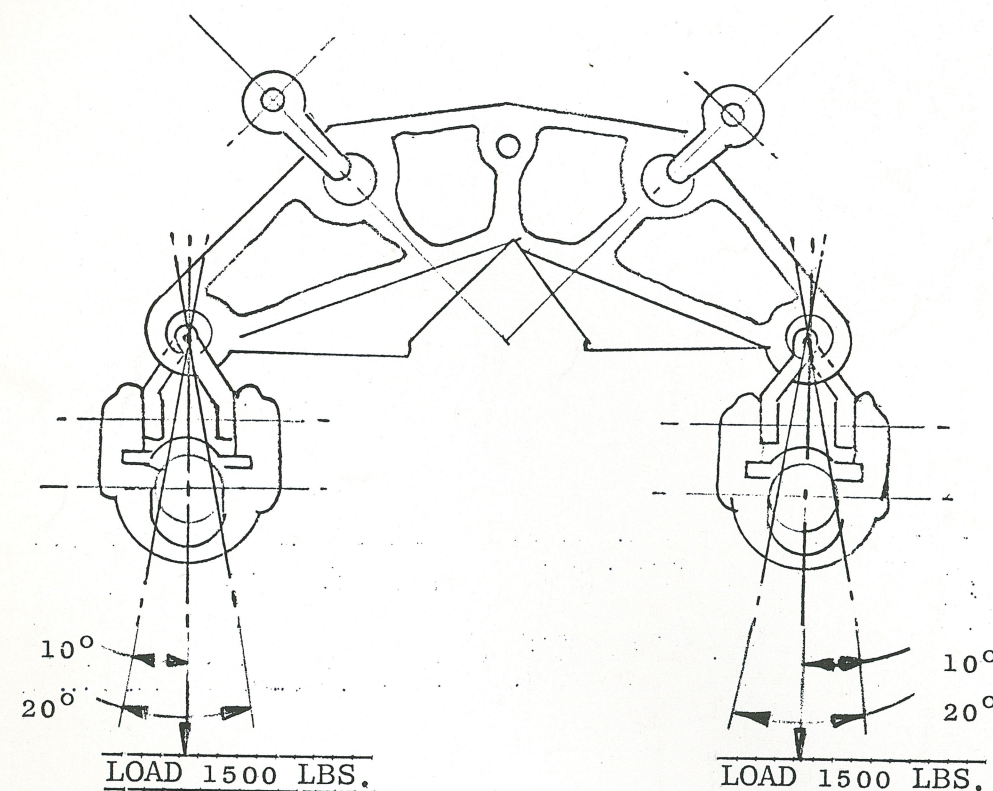
THIS CORONA RING USED FOR  
MID TAP TERMINAL  
WITH TOP 3 RACKS SHORTED







ON TANGENT TOWERS GREATEST WEAR IS EXPECTED TO OCCUR AT THE TOP OF SINGLE INSULATOR STRINGS AND AT THE CLAMP ATTACHMENT POINTS ON "V" STRINGS.



TESTS WERE INTENDED TO SIMULATE CONDITIONS SUCH AS MIGHT OCCUR ON A TANGENT "V" STRING SUSPENSION ASSEMBLY IN NORMAL SERVICE WITH A MEDIUM CROSSWIND APPROXIMATELY AT RIGHT ANGLES TO THE LINE. VERTICAL LOADS WERE TYPICAL OF THOSE EXPECTED UNDER NORMAL CONDITIONS FOR A LINE USING HEAVY CONDUCTOR AND MEDIUM-TO-LONG SPANS; NO ICE.

CLAMPS, UNDER LOAD, WERE SWUNG TWENTY DEGREES (20°), TEN DEGREES (10°) EACH SIDE OF CENTER LINE, AT A RATE OF TWENTY (20) CYCLES PER MINUTE.

SALES-ENGINEERING  
BULLETIN  
1166-A

AN ABBREVIATED REPORT COVERING COMPARATIVE  
WEAR TESTS PERFORMED ON SUSPENSION  
ASSEMBLY HARDWARE

NOVEMBER, 1966



THIS BULLETIN DISTRIBUTED BY YOUR G. E. INSULATOR  
DEPT. SALES REPRESENTATIVE \_\_\_\_\_

**BETHEA COMPANY**

LINE EQUIPMENT FOR THE ELECTRICAL POWER INDUSTRY

P. O. BOX 1407

INCORPORATED

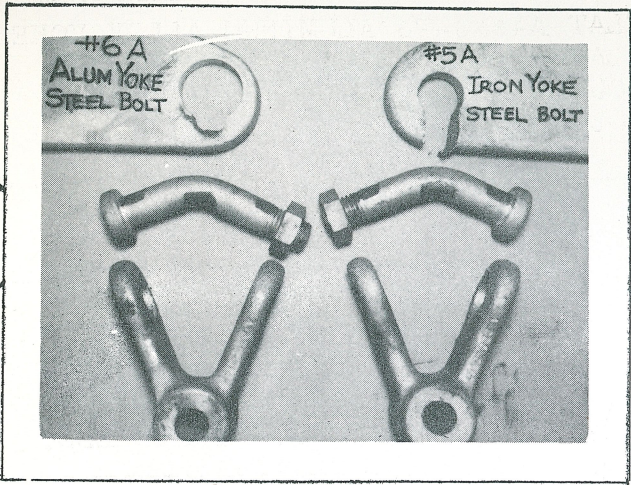
BIRMINGHAM 1, ALABAMA



THESE PHOTOGRAPHS SHOW RESULTS OF WEAR TESTS MADE ON SETS OF IDENTICAL ALUMINUM AND FERROUS YOKES UNDER IDENTICAL CONDITIONS. THE TEST PARAMETERS WERE TYPICAL OF THOSE EXPECTED IN ACTUAL FIELD APPLICATIONS UNDER NORMAL CONDITIONS. NO ATTEMPT WAS MADE TO EQUATE THE TEST RESULTS WITH ACTUAL LINE LIFE. THE TESTS STRONGLY INDICATE THAT BETHEA ALUMINUM ALLOY YOKE PLATES WILL OUTWEAR IDENTICAL FERROUS PLATES. CLEARLY SHOWN WAS THE ADVANTAGE OF THE BETHEA SPECIALLY SHAPED BEARING AREAS. ALSO, THE TESTS RENDERED VALUABLE INFORMATION USEFUL FOR THE DESIGN OF IMPROVED CONNECTING HARDWARE FOR THE SUSPENSION CLAMP AND COLD END ATTACHMENT POINTS.

FLAT A-356-T6 ALUMINUM ALLOY YOKE PLATE, 5/8" THICK, WITH C-1040 DOUBLE HEAT TREATED BENT STEEL BOLT.

- DATA -  
CYCLES: 579,805  
HOURS: 510.4  
SWING: 20°  
CYCLES/MIN.: 20  
LOAD: 1,500 LBS.



FLAT IRON YOKE PLATE, 5/8" THICK, WITH C-1040 DOUBLE HEAT TREATED BENT STEEL BOLT.

- DATA -  
CYCLES: 155,100  
HOURS: 130.2  
SWING: 20°  
CYCLES/MIN.: 20  
LOAD: 1,500 LBS.

FIG. 1

A-356-T6 ALUMINUM ALLOY YOKE PLATE WITH SPECIALLY FORMED AND ENLARGED BEARING AREAS. THE BENT CLEVIS BOLT IS C-1040 DOUBLE HEAT TREATED STEEL.

- DATA -  
CYCLES: 627,336  
HOURS: 524.4  
SWING: 20°  
CYCLES/MIN.: 20  
LOAD: 1,500 LBS.

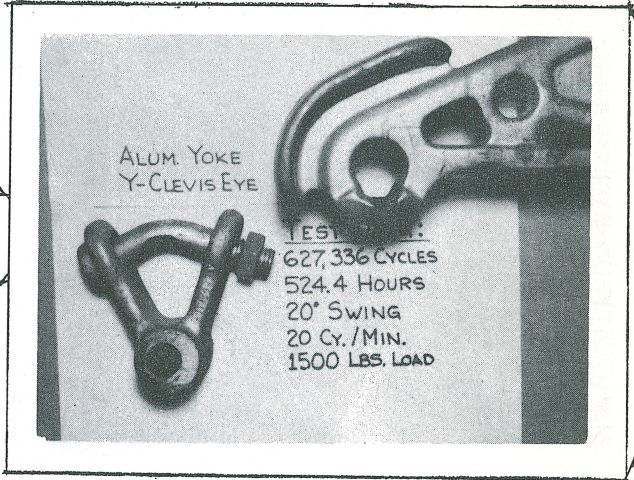


FIG. 2-A

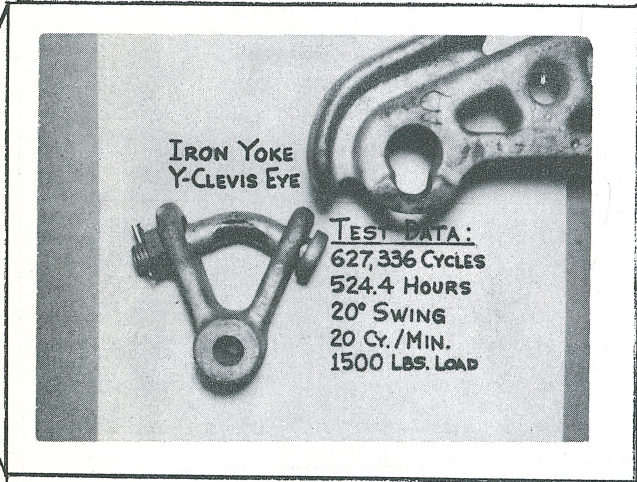


FIG. 2-B

IRON YOKE PLATE WITH SPECIALLY FORMED AND ENLARGED BEARING AREAS. THE BENT CLEVIS BOLT IS C-1040 DOUBLE HEAT TREATED STEEL.

- DATA -  
CYCLES: 627,336  
HOURS: 524.4  
SWING: 20°  
CYCLES/MIN.: 20  
LOAD: 1,500 LBS.

FLAT, A-356-T6 ALUMINUM ALLOY YOKE PLATE, 5/8" THICK, WITH C-1040 DOUBLE HEAT TREATED BENT STEEL BOLT.

- DATA -  
CYCLES: 236,350  
HOURS: 198.05  
SWING: 20°  
CYCLES/MIN.: 20  
LOAD: 1,500 LBS.

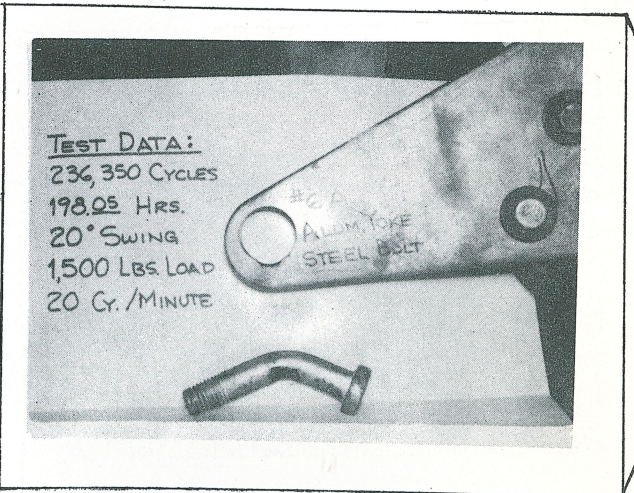


FIG. 3-A

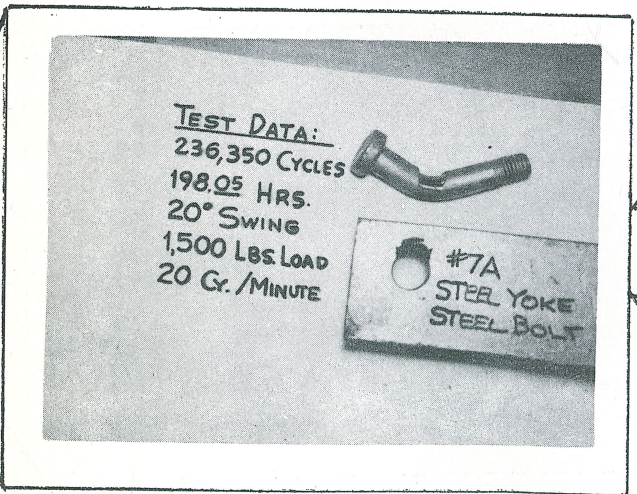


FIG. 3-B

FLAT, C-1018-20, HOT ROLLED, 5/8" THICK, STEEL PLATE WITH C-1040 DOUBLE HEAT TREATED BENT STEEL BOLT. NOTE WEAR ON BOLT.

- DATA -  
CYCLES: 236,350  
HOURS: 198.05  
SWING: 20°  
CYCLES/MIN.: 20  
LOAD: 1,500 LBS.

NOTE 1: FOR A DISCUSSION OF LOADING CONDITIONS, SEE BACK PAGE.  
NOTE 2: BETHEA TESTS INDICATE THE WEAR RATE INCREASES, APPROXIMATELY, AS THE SQUARE OF THE LOAD-INCREASE RATIO. AT 3,000 POUNDS LOAD THE WEAR RATES WOULD BE ABOUT FOUR TIMES AS HIGH AS THOSE FOR THE 1,500 POUNDS LOAD SHOWN.